METABOLISM AND NUTRITION

Dietary Lysine Needs of Late-Developing Heavy Broilers

A. Corzo,*[1] W. A. Dozier, III,† and M. T. Kidd*

*Department of Poultry Science. Mississippi State University, Mississippi State 39762; and †United States Department of Agriculture, Agriculture Research Service, Mississippi State 39762

ABSTRACT Two studies were conducted to determine the response of late-developing broiler males and females to dietary Lys from 42 to 56 d of age. Hubbard Ultra Yield males and females were placed at separated ends of a floor pen broiler house and raised on common diets. At 42 d of age, broilers were then fed 1 of 7 gradient concentrations of dietary Lys that progressively increased by 0.07% from 0.68 to 1.10% total Lys. Regression analysis was performed to estimate dietary Lys needs in the presence of quadratic responses. Female broilers did not respond to dietary Lys for any variable measured. Gradient additions of Lys improved feed conversion linearly ($P < 0.01$) for male broilers. Fillet weight, tender weight, and their composite increased linearly ($P < 0.05$) with Lys supplementation in male broilers. Quadratic responses were exhibited by carcass yield, fillet yield, and total breast meat yield, resulting in total Lys optimization dietary levels of 0.88, 0.93, and 0.93%, respectively, in male broilers. Based on results from this study, high-yield male broilers should be fed a minimum of 0.93% total dietary Lys (0.85% calculated digestible) from 42 to 56 d of age. Lack of response by female broilers suggests that less dietary Lys may be needed for adequate growth and meat yield.

Key words: amino acid, breast yield, broiler, lysine

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INTRODUCTION

Essential amino acid recommendations for broilers by the NRC (1994) are largely based on experimentation conducted several decades ago. Current amino acid requirements for broilers in stages prior to market are sparse and inconclusive. Broilers are constantly being genetically selected for an increase in their growth rates and other desired traits. To fulfill dietary needs associated with this additional growth, levels of limiting amino acids commercially used such as Lys, Met, and Thr have generally increased (NRC, 1994). Most of these amino acids are now being supplemented in crystalline or synthetic form, enabling dietary CP to decrease below NRC (1994) recommendations and improving overall balance.

Current recommendations of 0.85% total Lys for broilers between 42 and 56 d of age originated from research conducted in the 1970s using common formulations without the benefit of most limiting amino acids in free form (NRC, 1994). Dietary Lys in most feed formulations at these ages is usually second-limiting and particularly important in assuring yield of skinless, boneless breast meat with today's broiler (Acar et al., 1991). Most nutritionists use Lys as the basis to which all other amino acids are related when generating an "ideal balance." Total Lys values used in practice have increased to approximate ≥0.95%, which has been supported by research on high breast meat-yielding strain crosses (Acar et al., 1991; Bilgili et al., 1992). However, data regarding Lys recommendations for high-yield heavy broilers based on actual experimentation and not by modeling are sparse.

This study examined Lys supplementation from a theoretically deficient level to an excessive level for high-yield broilers between 42 and 56 d of age. Measurements involved live performance and carcass yields.

MATERIALS AND METHODS

Bird Husbandry

Hubbard Ultra Yield male and female 1-d-old chicks were randomly distributed at separate ends of an open-sided house into floor pens with thermostatically controlled heating, curtains, and cross-ventilation (48 pens per gender; 12 birds per pen; 0.09 m^2 per bird). Although all birds in the house were exposed to identical experimental conditions, males were purposely placed on one end of the house, and females were placed on the opposite end so that each sex was treated as a separate study and analyzed as such. Each pen used litter and was equipped with a nipple drinker line (3 nipples per pen) and a hanging feeder (22.5-kg capacity). The lighting

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[1]Corresponding author: acorzo@poultry.msstate.edu

Table 1. Composition of experimental diets (%, as-fed basis)

Ingredient	Common feed: Starter (0 to 21 d)	Common feed: Grower (21 to 42 d)	Experimental feed (42 to 56 d): Control	Experimental feed (42 to 56 d): Dose-response[1]
Corn	60.39	64.92	71.85	77.46
Soybean meal (48% CP)	29.95	25.69	21.37	15.65
Pet food-grade poultry meal (65% g/kg of CP)	4.0	4.0	—	—
Poultry fat	2.54	2.14	2.89	2.12
Dicalcium phosphate	1.36	1.11	1.72	1.76
Calcium carbonate	0.99	0.89	1.09	1.09
Salt	0.46	0.47	0.45	0.45
DL-Met	0.27	0.23	0.25	0.31
Vitamin and mineral premix[2]	0.25	0.25	0.25	0.25
L-Lys HCl	0.22	0.22	0.15	—
Salinomycin[3]	0.05	0.05	—	—
Filler[4]			—	0.55
L-Thr	0.017	0.035	—	0.084
L-Arg	—	—	—	0.172
L-Val	—	—	—	0.069
L-Ile	—	—	—	0.038
L-Trp	—	—	—	0.015
			—	
Calculated composition				
ME (kcal/kg)	3,080	3,140	3,200	3,200
CP (%)	22.7	20.9	17.0	15.0
Calcium (%)	0.94	0.84	0.82	0.82
Available phosphorus (%)	0.47	0.42	0.41	0.41
Lys, total (%)	1.33	1.22	0.96	0.68
Lys, digestible (%)	1.20	1.10	0.86	0.60
TSAA, digestible (%)	0.89	0.81	0.75	0.75
Thr, digestible (%)	0.75	0.71	0.55	0.55

[1]Calculated and analyzed (in parenthesis) total Lys values (% of diet) for the dose-response diet were 0.68 (0.67), 0.75 (0.73), 0.82 (0.81), 0.89 (0.88), 0.96 (0.93), 1.03 (0.99), 1.10 (1.09). The control dietary Lys concentration value was 0.96 (0.93).

[2]The vitamin and mineral premix contained per kg of diet: retinyl acetate, 2,654 μg; cholecalciferol, 110 μg; DL-α-tocopherol acetate, 9.9 mg; menadione, 0.9 mg; B_{12}, 0.01 mg; folic acid, 0.6 mg; choline, 379 mg; D-pantothenic acid, 8.8 mg; riboflavin, 5.0 mg; niacin, 33 mg; thiamin, 1.0 mg; D-biotin, 0.1 mg; pyridoxine, 0.9 mg; ethoxiquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 0.5 mg; selenium, 0.1 mg; myco-lock adsorbent, 0.05% of diet; santoquin, 0.02% of diet.

[3]Dietary inclusion of 60 g of salinomycin sodium/907.2 kg of feed.

[4]Filler represents inert space (sand) in the diet to which L-Lys-HCl was added to derive the projected Lys level.

program consisted of 23 h of light and 1 h of darkness. Ventilation was accomplished by negative air pressure. Chicks were vaccinated for Marek's disease (via in ovo administration at d 18) and Newcastle disease and infectious bronchitis (via coarse spray at hatch). All birds received common corn and soybean meal feeds from placement to 21 d of age in crumbled form and as whole pellet from 21 to 42 d (Table 1), each of which met or exceeded NRC (1994) nutrient recommendations.

Treatments

At 42 d of age, bird number was equalized among pens (10 birds per pen; 0.1 m^2 per bird); then, treatments were assigned to pens to provide a similar distribution of average bird weight at the start of both experiments. Treatments consisted of 7 dietary Lys levels (6 replications) that progressed from 0.68 to 1.10% total Lys (0.60 to 1.02% calculated digestible). To ensure uniformity of mix, a common dose-response basal diet batch was made in a vertical mixer. Random aliquots of the dose-response diet were used to derive the dietary increments of Lys, accomplished by the addition of L-Lys-HCl at the expense of an inert filler. Composite samples of dietary treatments were obtained and analyzed for protein-bound and supplemented amino acids (Llames and Fontaine, 1994) to ensure that calculated and analyzed Lys values were in agreement. In both studies, an isocaloric corn and soybean meal diet with 17% CP served as the control (6 replications). Formulation of the basal diet (Table 1) minimized Lys content (0.68%) while assuring the minimum levels of all other essential amino acids in a manner that would meet or exceed current NRC (1994) recommendations. Feed and water were offered ad libitum.

Measurements

The mean bird weight of all pens was recorded at the initiation and termination of the experiments. Feed consumption and mortality were recorded. Feed conversion was corrected for mortality and represents grams of feed consumed by all birds in a pen divided by grams of BW gain per pen. At 56 d of age, 6 birds per pen were

Table 2. Growth performance of broiler males and females fed diets differing in dietary Lys from 42 to 56 d of age[1]

	Males			Females		
Total dietary Lys (%)	BW gain (kg)	Feed intake (kg)	Feed conversion[2]	BW gain (kg)	Feed intake (kg)	Feed conversion[2]
0.68	1.042	2.388	2.30	0.810	1.987	2.47
0.75	1.040	2.387	2.30	0.861	2.004	2.34
0.82	1.114	2.353	2.13	0.849	1.947	2.30
0.89	1.047	2.309	2.20	0.867	1.989	2.31
0.96	1.153	2.380	2.07	0.883	1.992	2.26
1.03	1.132	2.356	2.09	0.846	1.991	2.39
1.10	1.101	2.360	2.15	0.803	1.894	2.40
Control (0.96% Lys)	1.145	2.302	2.03	0.874	1.961	2.31
SEM	0.0454	0.0555	0.056	0.0413	0.0528	0.061
ANOVA (*P*)						
Lys	0.25	0.99	0.27	0.61	0.69	0.53
Lys linear	0.10	0.62	0.009	0.93	0.36	0.83
Lys quadratic	0.42	0.59	0.11	0.07	0.46	0.13

[1]Values represent least squares means of 6 replicate pens, each with 10 birds at 42 d of age.

[2]Values represent feed consumed divided by BW gain (kg/kg) corrected for mortality.

weighed and cooped 12 h before processing. Processing was manual, and carcass and abdominal fat weights were obtained and recorded. Carcasses were chilled for 4 h, and the breast muscles were manually deboned. The incidence of deep pectoral myopathy in pectoralis minor muscles was recorded.

Statistical Analyses

Data in both experiments were evaluated by ANOVA in a completely randomized design. Pen was used as the experimental unit for analysis. Percentage data for mortality and incidence of deep pectoral myopathy were transformed to arcsine $\sqrt{\%}$ for analysis. All data were analyzed by the GLM procedure of SAS (1996). Lysine effects ($P \leq 0.05$) were separated using the LSD option of SAS (1996) with an α of 0.05. Only linear and quadratic effects are presented on the respective tables because significance ($P > 0.05$) of higher order polynomials was not observed. Regression analysis was used to estimate Lys optimization (95% of the maximum or minimum response) whenever a significant quadratic response ($P < 0.05$) was observed.

RESULTS AND DISCUSSION

Live performance of broilers prior to initiation of both experiments was favorable (grand means: male BW = 2.58 kg, SEM = 0.0441; female BW = 2.16 kg, SEM = 0.0412; overall mortality = 2.1%). Calculated and analyzed dietary Lys levels were in close agreement (Table 1). Broiler males and females fed the control diet showed BW gain, feed intake, and feed conversion values (Table 2) similar to those fed the dose-response diet with an equal amount of total dietary Lys (0.96%). Consequently, the dose-response diet was validated, proving to be adequate for maximal growth performance.

Male broilers responded to dietary Lys more acutely than females. A linear improvement in feed conversion was observed for male broilers as Lys was supplemented

Table 3. Carcass and abdominal fat weight and yield of broiler males and females fed diets differing in dietary Lys from 42 to 56 d of age[1]

	Males				Females			
Total dietary Lys (%)	Carcass weight (kg)	Carcass yield (%)[2]	Abdominal fat weight (g)	Abdominal fat (%)	Carcass weight (kg)	Carcass yield (%)	Abdominal fat weight (g)	Abdominal fat (%)
0.68	2.60	70.4	74	2.83	2.10	70.4	81	3.83
0.75	2.59	70.6	70	2.71	2.06	70.0	81	3.93
0.82	2.55	71.1	72	2.81	2.12	70.5	79	3.69
0.89	2.68	71.4	71	2.64	2.10	70.1	80	3.80
0.96	2.63	71.7	68	2.59	2.13	70.1	82	3.84
1.03	2.63	71.0	72	2.75	2.14	70.0	80	3.77
1.10	2.59	70.8	68	2.63	2.13	70.5	87	4.06
SEM	0.032	0.39	3.9	0.138	0.029	0.29	4.0	0.199
ANOVA (*P*)								
Lys	0.35	0.33	0.93	0.89	0.66	0.29	0.89	0.91
Lys linear	0.52	0.33	0.43	0.30	0.67	0.67	0.35	0.61
Lys quadratic	0.42	0.04	0.90	0.84	0.36	0.36	0.33	0.35

[1]Values represent least squares means of 6 replicate pens, each providing 6 carcasses.

[2]Quadratic equation: $Y = 0.566 + 0.319\ (\text{Lys}) - 0.173\ (\text{Lys})^2$, resulting in a total dietary Lys optimization value of 0.88% of diet (0.80 digestible Lys).

Table 4. Fillets (Pectoralis major), tenders (Pectoralis minor), and total breast meat weights and yields and incidence of deep pectoral myopathy of broiler males fed diets differing in dietary Lys from 42 to 56 d of age[1]

Total dietary Lys (%)	Fillets		Tenders		Total breast			Deep pectoral myopathy (%)
	Weight (g)	Yield (%)[2]	Weight (g)	Yield (%)	Weight (g)	Yield-C[3]	Yield-BW[4]	
0.68	612^{b}	23.5^{b}	139	5.33	751^{b}	28.8^{c}	20.3^{c}	0.0^{b}
0.75	615^{b}	23.8^{b}	141	5.48	757^{b}	29.3^{bc}	20.7^{bc}	13.3^{a}
0.82	615^{b}	24.1^{b}	137	5.36	752^{b}	29.5^{bc}	21.0^{abc}	0.0^{b}
0.89	662^{a}	24.7^{a}	148	5.53	810^{a}	30.3^{ab}	21.6^{a}	0.0^{b}
0.96	639^{abc}	24.3^{ab}	148	5.64	787^{ab}	29.9^{ab}	21.5^{ab}	0.0^{b}
1.03	654^{a}	24.9^{a}	148	5.62	802^{a}	30.5^{a}	21.6^{a}	0.0^{b}
1.10	628^{ab}	24.2^{ab}	147	5.67	776^{ab}	29.9^{ab}	21.2^{abc}	10.0^{ab}
SEM	11.8	0.29	3.6	0.100	14.3	0.34	0.29	3.6
ANOVA (*P*)								
Lys	0.02	0.01	0.13	0.11	0.02	0.008	0.02	0.04
Lys linear	0.04	0.007	0.01	0.002	0.02	0.001	0.003	0.80
Lys quadratic	0.20	0.05	0.92	0.98	0.27	0.08	0.03	0.27

[a-c]Means within a column not sharing a common superscript differ ($P < 0.05$).

[1]Values represent least squares means of 6 replicate pens, each providing 6 carcasses.

[2]Quadratic equation: $Y = 11.32 + 27.16\,(Lys) - 13.89\,(Lys)^2$, resulting in a total dietary Lys optimization value of 0.93% of diet (0.85% digestible Lys).

[3]Values are expressed as total breast meat relative to the carcass.

[4]Values are expressed as total breast meat relative to the live weight. Quadratic equation: $Y = 7.312 + 29.053\,(Lys) - 14.860\,(Lys)^2$, resulting in a total dietary Lys optimization value of 0.93% of diet (0.85% digestible Lys).

(Table 2). An improvement in feed conversion with Lys supplementation concurrently with no effect on BW gain had been previously observed in Ross 308 male birds from 6 to 8 wk of age (Corzo et al., 2003). No apparent effect on live performance was observed in female broilers associated with Lys supplementation (Table 2). Mortality was minimal (0.9%) for the period between 42 and 56 d of age and was not affected by dietary Lys.

After processing of both males and females, a quadratic response to Lys was observed in males for carcass yield (Table 3). After regression analysis, it was estimated that male broilers required a minimum of 0.88% total Lys (0.80% digestible) for maximization of carcass yield. In male broilers, an effect of dietary Lys on carcass yield has been previously observed (Kidd et al., 1998; Kidd and Fancher, 2001). Abdominal fat weight and proportion were unaltered by dietary Lys in male broilers. In female broilers, no effect of dietary Lys on female broilers was observed for carcass and abdominal fat weight and yield (Table 3).

An increase in breast meat yield when formulating diets with Lys levels above those recommended has been shown (Hickling et al., 1990; Moran and Bilgili, 1990; Bilgili et al., 1992; Kidd et al., 1997, 1998). Although there appears to be general agreement concerning the effect that dietary Lys has on breast meat yield, there is little agreement on the level to be fed to heavy broilers. Because of the increase in associated variability in heavy broilers, data are sometimes inconclusive. In the present study, we were able to obtain responses for male broilers that allowed an estimation of dietary Lys needs for breast meat optimization (Table 4). A linear increase in fillet (pectoralis major) weight, tender (pectoralis minor) weight and yield, and total breast meat weight was observed with increasing Lys supplementation. Furthermore, fillet yield and total breast yield exhibited qua-

Table 5. Fillets (Pectoralis major), tenders (Pectoralis minor), and total breast meat weights and yields and incidence of deep pectoral myopathy of broiler females fed diets differing in dietary Lys from 42 to 56 d of age[1]

Total dietary Lys (%)	Fillets		Tenders		Total breast		Deep pectoral myopathy (%)
	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)[2]	
0.68	509	24.2	127	6.05	636	30.2	3.4
0.75	501	24.3	123	5.98	624	30.3	6.9
0.82	512	24.1	128	6.04	641	30.1	3.4
0.89	512	24.3	125	5.93	637	30.3	9.8
0.96	509	23.9	132	6.19	641	30.0	0.0
1.03	529	24.8	125	5.85	654	30.6	3.3
1.10	519	24.4	127	5.93	646	30.3	3.2
SEM	9.3	0.36	3.3	0.121	11.3	0.39	4.45
ANOVA (*P*)							
Lys	0.57	0.73	0.59	0.54	0.73	0.96	0.81
Lys linear	0.15	0.49	0.81	0.47	0.21	0.68	0.66
Lys quadratic	0.79	0.68	0.76	0.69	0.89	0.80	0.68

[1]Values represent least squares means of 6 replicate pens, each providing 6 carcasses.

[2]Values are expressed as total breast meat relative to the carcass.

dratic responses, allowing regression to estimate optimal dietary levels occurring at 0.93% total dietary Lys for both parameters (0.85% digestible). Conversely, female broilers were unaffected by dietary Lys for any breast muscle parameter evaluated (Table 5).

Deep pectoral myopathy in broilers has long been known to be a necrosis, resulting in progressive wasting and muscle loss (Richardson et al., 1980; Siller, 1985). An increase in the incidence of deep pectoral myopathy was observed at a dietary Lys level of 0.75% in males but not in females (Table 4). These results are in disagreement with previously reported effects that showed a linear increase in the incidence of this meat defect when dietary Lys was increased in heavy male broilers (Corzo et al., 2002). Even though results in this study and those reported by Corzo et al. (2002) show an influence of dietary Lys on the incidence of myopathy, an explanation for any increase or decrease in its occurrence caused by Lys is elusive.

It is of utmost importance to adequately supply dietary levels of the most limiting amino acids, such as Lys. This ensures optimal growth and yield of saleable boneless, skinless white meat. Furthermore, defining the nutrient recommendation of Lys during the 42- to 56-d feeding phase allows a nutrient minimum to be inserted for feed formulation, in turn, minimizing amino acid excess and assuring minimal cost per kilogram of feed, considering the high feed consumption by birds at this age. Given the present experiment, it can be concluded that the advocated requirement by the NRC (1994) of 0.85% total Lys for the 42- to 56-d period is low for optimal performance of modern commercial high-yield male broilers. An overview of all measurements in this study suggests that 0.93% total dietary Lys approximates an optimal level (0.85% digestible) for high-yield heavy male broilers grown to heavy weights, whereas female broilers are likely to necessitate less.

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